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NO DRAWINGS

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COMPLETE SPECIFICATION

Manufacture of Daylight Projection Screens

We, SUMITOMO CHEMICAL COMPANY LIMITED, 15 5-chome, Kitahama, Higashi-ku, Osaka, Japan, a Japanese Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of manufacturing a daylight projection screen to be used for viewing in daylight an image of a slide film or a movie film projected on it.

It has been customary to project a slide or movie film in a dark room with a projector on to a white screen made of fabric. Demands have arisen, however, for dispensing with a screen for projection in darkness, and there has been a consequential designing and development of apparatuses to enable observation of such projected images in daylight.

The fundamentals of such an apparatus is a device for the formation of the image by light rays from the source passing through a slide, or film, on a daylight projection screen by a lens system and for observation of said image on said screen from the opposite side. Such a daylight projection screen must therefore have properties which enable the viewing of a clear and bright image even in daylight. For this purpose, ordinary frosted glass could satisfy the requirement to some extent, but the use of such a material is unsatisfactory because the image formed on the back of the screen is very low in diffusion, which makes a bright centre and a dark edge when the image is viewed from the centre, or the brightness of the image varying considerably according to the viewing angle when observed diagonally.

A daylight screen must therefore be satisfactory in the diffusion of light and must also be high in the transmission of light for producing a bright image. An image thus formed by projection must be bright in detail, be free from whitening of the image caused by the reflection of external light on the screen, and, desirably, be satisfactory in colour reproducibility in the relation between colour and temperature of the source.

The present invention provides a method of manufacturing a daylight projection screen which satisfies the aforesaid requisite properties of a daylight screen. It also provides such daylight projection screens.

A daylight projection screen according to the present invention consists of a substrate and a light-diffusion layer firmly adhering thereto. The diffusion layer consists of a light-diffusing medium, a binder, and preferably dyestuffs and pigments for the absorption of stray light and for colour control.

Irregular reflection on a boundary between materials can be utilised for improving the diffusion of light, and this requires the use of minute reflecting and refracting surfaces facing various directions. A method of obtaining this is to disperse particles of a light-diffusion medium in a binder of different refractive index to form a diffusion layer which will cause scattering of the light. In this case, a greater diffusion of light is obtainable from a greater difference in refractive index, but an excessively large difference in this results in a lower transmission, and a smaller difference in refractive index results in a poorer diffusion. A diffusion layer must be thick for a satisfactory diffusion, but this causes deterioration of the definition of the image, while too thin a diffusion layer makes a uniform coating on the substrate difficult. Therefore the thickness of the diffusion layer should preferably be limited to within an approximate range of 20 to 200μ. It has been found that a difference, (Δn), in refractive index between the light-diffusing medium and the binder must be over 0.02, and that the maximum value of Δn is 0.3 to obtain a satisfactory diffusion layer.

Diffusion of light is affected not only by a difference in refractive index and diffusion-layer thickness but also by the particle size of the light diffusion medium. A smaller par-

ticle size improves diffusion and image resolving power, but particles which are too small tend to produce secondary particles which cause difficulty in preparing the light diffusion medium. Because of these reasons, the use of particles measuring about 1 to 20μ is normally preferred.

It has also been found that a certain fixed relation holds between diffusion of light and transmission of light which remains substantially unaffected by different combinations of light-diffusing medium and binder, particle size and shape, and diffusion-layer thickness. That is, expressing diffusion by the following equation (1), an approximately linear relation holds between the logarithm of diffusion, (log D), and the logarithm of transmittance of light, (log T_θ), at the photometric angle, ($\theta°$), where diffusion factor, (D), is less than 0.90.

$$D = \frac{B_{20°} + B_{70°}}{B_{5°}} \quad \cdots\cdots\cdots \quad (1)$$

$$B_\theta = \frac{T_\theta}{\mathrm{Cos}_\theta} \quad \cdots\cdots\cdots \quad (2)$$

D = diffusion factor

B_θ = brightness

T_θ = transmittance

θ = angle

Transmission, (T_θ), above can be measured with an ordinary light diffusion apparatus.

For example, with a combination of quartz powder as a light-diffusion medium and polymethyl methacrylate as a binder, or with a combination of silica gel as a light-diffusion medium and polyvinyl chloride as a binder, a smaller particle size results in a greater diffusion factor, (D), and a smaller transmission, (T_o), to almost equal degrees. Notwithstanding a difference in type or particle size of the light diffuser, the kind of binder or thickness of diffusion layer, virtually the same value in transmittance, (T_o), results as long as the diffusion, (D), is the same. This relation does not hold, however, where the diffusion factor, (D), exceeds 0.9, which pertains to an almost perfect diffuser.

The substrate of a daylight projection screen must have adequate mechanical strength for holding a diffusion layer, transparency and a good light fastness. For these reasons, the substrate is preferably made of glass, polymethyl methacrylate, polystyrene, rigid polyvinyl chloride and other transparent plastics for a rigid daylight screen and soft polyvinyl chloride resins for roll-up soft daylight screen.

The binder should be a material which bonds firmly with the substrate and which, in combination with the diffusing medium, has a difference in refractive index of from 0.02 to 0.3. Where the substrate is a plastics material, the binder is preferably of the same material.

As a diffusing medium, use can be made of substances which satisfy the aforesaid refractive index criterion and which can be crushed finely, but it is preferred to use powders of such inorganic substances as quartz, silica gel, glass and alumina.

A combination of a binder and a light-diffusing medium can be determined in accordance with the type of the daylight projection screen required. The dispersion of a light-diffusing medium in a binder can be made by mixing the diffusing medium in the binder which has been dissolved in a solvent. Alternatively, where the binder is a plastics material it may be convenient to disperse the light-diffusing medium in the liquid monomer from which the plastics material is produced, then to form a layer of this dispersion of appropriate thickness on the surface of the substrate, and there cause the monomer to polymerise. This method is particularly appropriate where the binder is polymethyl methacrylate.

It is desirable to mix an absorber for scattered light in the diffusion layer for minimising the effects of such external light. A black pigment is generally used for this purpose. It can be common carbon black. The use of a large amount of carbon black results in the absorption of a large amount of stray light, but a lower transmittance of light, therefore an appropriate range of from 0.01 to 0.06% by weight of carbon black in the diffusion layer is generally suitable for a diffusion layer as a whole.

A blue dye is added for improving colour reproducibility by removing the yellowness in a commonly-used light source. Its amount varies according to the type of source used, but it is usual to use about one-fifth of the amount of carbon black.

Daylight projection screens varying in diffusion and transmission are obtainable by the above method, but for practical purposes, one having a diffusion factor, (D), range of iron from 0.2 to 0.8 and a corresponding transmission, (T_o), of from 6 to 12% gives a balance between diffusion and brightness.

A method of manufacturing a daylight screen will now be discussed.

A light-diffusing medium is first crushed finely in a ball mill or crusher. This is followed by precipitation from a suspension of these fine particles in a liquid, or other suitable method, for classification, to obtain particles within a range of from 1 to 20μ. It is

necessary for the light-diffusing medium to have a difference in refractive index within a range of 0.02 to 0.3 from that of a binder, and to have a satisfactory adhesion to a substrate, and it is desirable to use a minimum quantity of the binder necessary for sufficient dispersion of the light-diffusing medium in the diffusion layer. This quantity varies slightly according to the type of light-diffusing medium, but it is normally a rate of about 1 part of a binder per 2 parts of light-diffusing medium. Where a solvent is used, it should be ready for use in a quantity required to give a suitable dispersion of the light-diffusing medium and binder for providing coating on the substrate. The light-diffusing medium, binder, dyestuff and pigment thus prepared can be homogeneously mixed, in a mixer such as a grinder or a mortar but in such manner that secondary particles are not formed. If necessary, the mixture is passed through a sieve of about 250 mesh in fineness for removing secondary particles. The mixture thus obtained is coated on the substrate in a uniform thickness with a coating machine such as a Baker applicator. The number of operations for the coating can be suitably increased to give a final coated diffusion layer thickness of from 20 to 200μ. The solvent is then completely removed by standing in air or by heating. Where a polymerisable monomer is used, the appropriate conditions are applied to cause it to polymerise. For example a light activated catalyst can be included in the mixture, and the coated substrate subjected to U.V. light to cause the monomer to polymerise. A daylight screen thus made sufficiently diffuses an image projected from its back which has a high definition and is sufficiently bright for viewing in daylight.

The method of grinding the light-diffusing medium, method of classification, the method of mixing light-diffusing medium, the method of coating, and the method of drying binder form no part of the present invention.

The invention is more fully illustrated by reference to the following examples.

Example 1

Commercial crushed quartz was ground for 24 hours in a ball mill by a wet method using toluene. The toluene was then removed, the ground quartz was suspended in water for the classification of particles by a precipitation method to within a range of from 1 to 5μ in size, and the water was evaporated until dryness was reached. The following materials in the stated amounts were placed in a mortar and thoroughly mixed.

Diffusing medium	Quartz (1 to 5μ) n= 1.54	2 parts by weight
Binder	Polymethyl methacrylate granules n = 1.49	1 part by weight
Solvent	Chloroform	5 parts by weight
Pigment	Carbon black	0.001 part by weight
Dyestuff	Cyanine Blue BCF*	0.0002 part by weight

*Trade name of a phthalocyanine colouring matter made by the Sumitomo Chemical Company Limited. The difference between the binder and the light-diffusing medium in refractive index Δn is 0.05.

The above coating composition was coated evenly by a Baker applicator on a substrate of a 3 mm thick polymethyl methacrylate sheet. The solvent was then dried in air to obtain a diffusion layer of thickness 90μ. The diffusion layer adhered firmly to the substrate. The daylight projection screen made thus had a diffusion factor D of 0.40 and a transmittance T_o of 2.8%. An image projected on the daylight screen by a projector and viewed in daylight was clear, there was little variation in brightness according to viewing angle, and it had sufficient brightness for viewing in daylight.

Example 2

Commercial colourless silica gel was ground and classified by the same method as in Example 1. Particles measuring 1 to 3μ were collected, and a coating compound was prepared by mixing at the same blending ratio as in Example 1. This mixture was coated on to a sheet of polymethyl methacrylate 3 mm. thick, and the solvent was evaporated to make a coating thickness of 90μ.

The silica gel had a refractive index n of 1.44, giving a difference Δn from that of the binder of 0.05. A daylight screen thus made had values of $D=0.430$ and $T_o=2.1\%$, which were similar to those in Example 1.

EXAMPLE 3

Commercial glass fibre having a diameter of 5μ was ground in a ball mill by the same method as in Example 1 and was classified to obtain a light-diffusing medium having a size range of 1 to 3μ. A daylight screen was obtained by using this after mixing with the following materials at the stated ratios by the same method as in Example 1.

Diffusing medium	Glass (1 to 3μ) n=1.54	2 parts by weight
Binder	Polymethyl methacrylate granules n=1.49	1.25 parts by weight
Solvent	Chloroform	5 parts by weight
Pigment	Carbon black	0.001 part by weight
Dyestuff	Cyanine Blue BCF	0.0002 part by weight

The difference between the refractive indices, diffusing medium and the binder, Δn, was 0.05. The diffusion layer had a thickness of 140μ. The daylight screen obtained had values $D = 0.55$ and $T_o = 2.5\%$, which were similar to those in Example 1.

EXAMPLE 4

A light-diffusing medium which was identical to that in Example 1 was mixed at the ratios stated below and coated on a soft polyvinyl chloride sheet by the method given in Example 1. The thickness of the diffusion layer after air drying the solvent was 95μ and the layer had an excellent adhesion to the sheet.

Diffusing medium	Quartz (1 to 5μ) $n_D = 1.54$	2 parts by weight
Binder	A mixture of 100 parts by weight of vinyl chloride-vinyl acetate copolymer VYHH (made by the Union Carbide Corporation) and 50 parts by weight of dioctyl phthalate n = 1.51	1 part by weight
Solvent	Methyl ethyl ketone	5 parts by weight
Pigment	Carbon black	0.001 part by weight
Dyestuff	Cyanine Blue BCF	0.0002 part by weight

The difference, Δn, in refractive index between the light-diffusing medium and the binder was 0.03.

The substrate was a soft sheet having a thickness of 0.2 mm. and consisting of 100 parts by weight of polyvinyl chloride and 50 parts by weight of dioctyl phthalate.

The daylight projection screen obtained thus was soft and could be rolled, and the values $D = 0.46$ and $T_o = 2.4\%$ were similar to those in Example 1.

WHAT WE CLAIM IS:—

1. A method of manufacturing a daylight projection screen in which there is applied to one surface of a transparent substrate a mixture of a light-diffusing medium and either a liquid polymerisable monomer that forms on polymerisation a transparent polymer which is a binder for the light-diffusing medium, or a transparent normally solid material which is a binder for the light-diffusing medium dissolved in a solvent therefor, and thereafter causing said monomer to polymerise or said solvent to evaporate, as appropriate, to form a diffusion layer, the difference between the refractive indices of the light-diffusing medium and binder being not less than 0.02 and not greater than 0.3.

2. A method according to claim 1 in which said substrate is a sheet of polymethyl methacrylate.

3. A method according to claim 1 or claim 2 in which said liquid polymerisable material is methyl methacrylate.

4. A method according to claim 1 or claim 2 in which said transparent normally solid material dissolved in a solvent therefor is polymethyl methacrylate.

5. A method according to any of the preceding claims in which said light-diffusing medium is a powdered inorganic substance.

6. A method according to claim 5 in which said light-diffusing medium is powdered quartz, silica gel, glass or alumina.

7. A method according to any of the preceding claims in which the particle size of the light-diffusing medium is from 1 to 20μ.

8. A method according to any of the preceding claims in which the diffusing layer has a thickness of 20 to 200μ.

9. A method according to any of the preceding claims in which said mixture contains additionally a light absorbent pigment.

10. A method according to claim 9 in which said pigment is carbon black.

11. A method according to claim 10 in which the amount of carbon black is from 0.01 to 0.06% by weight of the diffusion layer.

12. A method according to any of the preceding claims in which said mixture contains a dyestuff.

13. A method according to claim 12 and claim 10 or 11 in which the amount of said dyestuff is about 1/5 of the weight of said carbon black.

14. A method according to claim 13 in which said dyestuff is a blue dyestuff.

15. A method according to any of the preceding claims in which the weight ratio of the light-diffusing medium to binder is about 2 to 1.

16. A method substantially as hereinbefore described with particular reference to the Examples.

17. A daylight projection screen whenever prepared by a method according to any of the preceding claims.

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